I, SCIENCE

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I,SCIENCE

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I,SCIENCE, FELIX OFFICE, BEIT QUADRANGLE,
PRINCE CONSORT ROAD, LONDON, SW7 2BB

TEL: 020 7594 8072
EMAIL: I.SCIENCE@IMPERIAL.AC.UK

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I,SCIENCE

The word 'communication' comes from the Latin, *communicare*, meaning 'to share.' Every day we share our thoughts, ideas and words with others. But communication goes far beyond the human world.

Animals communicate with each other to attract others, as you can see in our list of animal courtship rituals on pg. 21. Even bacteria can communicate to coordinate an attack on their host, as we learn on pg. 10.

Our bodies themselves are a continually-communicating entity. We take you to the moment of birth on pg. 18 when the foetus has to communicate its readiness to enter the world and the mother's body must respond accordingly. Within our brain is a complex mesh of communicating signals, yet how do we communicate when this breaks down? On page 19 we discuss how doctors might be able to communicate with unresponsive coma patients.

Language, of course, is the most direct way that we communicate with each other. Humans can learn multiple languages and dialects, and we explore the advantages of multilinguality on pg. 6. Beyond spoken language, we take a look at the science and history of cryptography on pg. 8 and see how we can keep our private communications secret.

Communication is the means by which information is shared and transferred across different bodies. We hope this tour of how meaning is conveyed, be it via chemical signalling, spoken language or a cryptex is thought-provoking enough to communicate about it with others. ■

JEN AND IONA

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DESIGNING OBJECTS FOR LONG-DURATION SPACE FLIGHTS

ANNE PETZOLD

New frameworks have been developed to design objects that ensure physiological and psychological wellbeing of astronauts in long-duration flights.

The constraints of object design for long-duration space travel naturally differ from ordinary object design, but can be informed by a range of state-of-the-art explorative design solutions that have tried to alleviate some of these concerns.

In a recent article in *Acta Aeronautica*, Tibor Balint and Ashley Hall from the Royal College of Art use research focusing on emotional design and user experience by Ortíz Nicolás at Imperial College, to propose a conceptual framework for the design of objects for long-duration space flight. They take into account more than the technical functionality of an object and instead aim to promote the psychological well-being of astronauts as well.

The approximate time it takes to travel to Mars is nine months, and any objects brought on the journey would be immensely restricted. Aside from physiological stress, astronauts may suffer from debilitating psychological stress due to the risky nature of the journey, social isolation and confinement, sleep disruption, sensory deprivation and/or plain boredom.

Balint and Hall list several promising examples of human-object interaction that could directly inform aeronautic object design. For instance, smart light installations can manipulate our perception of space to efficiently increase its perceived expanse, alleviating a sense of confinement. And a robot or artificial intelligence system may be an efficient way to alleviate feelings of boredom and isolation.

Balint and Hall close with a loose list of 'design principles' for objects used in long-duration space flight, focusing on their psychological user needs. ■

Anne Petzold is a second year PhD student studying Neuroscience

NO ACUTE ADVERSE RESPONSES TO ASPARTAME

TOM GORDON

A recent paper published in *PLOS* has investigated the potential side-effects of aspartame to self-declared 'aspartame sensitive' individuals, those that 'reported suffering one or more symptoms on multiple occasions and as a consequence were actively avoiding consumption of any aspartame in their diet'.

The study was conducted by an international team that included members from the University of Hull and Imperial College London. Even they struggled to find volunteers willing to ingest the sweetener, such is the fear it provokes. The researchers hid 100 mg of aspartame (equivalent to a can of Diet Coke) in some cereal bars and left others untouched. The participants wouldn't know what they were eating. Various biological and psychological measures were recorded and compared to a control group.

The team found no differences in reported symptoms when comparing the aspartame bars to the controls. Whilst the study can only account for acute conditions rather than the chronic ones that are so often reported, it should offer some reassurance as to aspartame's safety.

The debate has however become entrenched in the political: the anti-aspartame 'holistics' see the sweetener as a product of dodgy corporate science that has been insidiously forced upon them. The fact that safety studies are often funded by ivory tower regulatory bodies is unlikely to sway support. ■

Tom Gordon is studying for a MSc in Science Communication

NEW INSIGHTS: THE HEALTH OF JULIUS CAESAR

ELEANOR MAGSON

Julius Caesar's health problems may have been caused by strokes, not epilepsy, according to recent research from Imperial College.

The medical ailments that affected Caesar were documented by ancient authors and are still discussed by today's historians. Caesar's symptoms were mainly described by Plutarch and Suetonius, historians both born after Caesar's death in 44BC. Symptoms described include falls, headaches, giddiness and vertigo, and have often been taken by modern scholars to suggest a diagnosis of epilepsy.

However, Francesco Galassi and Hutan Ashrafian from the Department of Surgery and Cancer at Imperial have re-assessed the historical documents and found that the symptoms could be attested to cerebrovascular disease, or strokes.

Strokes are caused by a disruption of the blood supply to the brain, resulting in a lack of oxygen delivery to the brain, which can cause weakness in the limbs and disruption of speech. Weakness in the limbs, or *paresis*, could have been the cause of Caesar's inability to stand for senators honouring him, or of the fall that led him to be carried away from the Battle of Thapsus in 46BC. According to Dr Galassi, cerebrovascular disease would be more logical to fit with these descriptions.

Caesar may have actually preferred a diagnosis of epilepsy. Known as the 'sacred disease,' and previously linked with genius, its connotations would have been more befitting for a member of Roman nobility. Alexander the Great was another possible sufferer of epilepsy, and Caesar and his successor Octavian may have wanted to emulate this great leader. Francesco Galassi says that the research has been well-received, but that there must be an attitude shift in how we view historical figures to lead to better understanding: "We look at them as marble statues and stick to the accepted theories. In my opinion we must respect the sources but give them a fresh, critical eye". ■

Eleanor Magson is studying for a MSc in Science Communication

RESEARCHERS DISCOVER HOW LOGGING ALTERS ECOSYSTEMS

STEPHANIE SAMMANN

Imperial College researchers have found that after logging in the Borneo rainforest, ecosystem processes like litter decomposition and seed dispersal are disrupted due to decreased abundance of key invertebrates.

These ecosystem processes do not come to a complete halt - instead, certain small mammals, amphibians, and birds step in to carry out these processes.

To discover the role of invertebrates in seed dispersal in primary (untouched, ancient) forest and logged forests, the researchers excluded invertebrates from access to seeds in both primary and logged forest and then tested dispersal rates. They found that the invertebrate contribution to dispersal is far more important in primary forest than in logged forests.
This is because vertebrates now carry out many of the essential ecosystem functions in logged forest in the absence of the invertebrates. So why are the invertebrates unable to carry out their ecological role of seed dispersal in logged areas, and why do vertebrates take over?

The researchers say the most likely explanation for the invertebrates' inability to maintain their role is the changed microclimate. Logging opens gaps in the rainforest canopy, increasing the forest's overall temperature. Soft-bodied invertebrates are particularly sensitive to drying out in heat, so their numbers have dropped in logged forests.

Vertebrate groups probably increase in abundance because of increased resource availability. Researchers found that logged forests were twice as likely to contain trees that are fruiting or flowering and the total invertebrate biomass was doubled in logged relative to primary forest, mainly with insects that do not disperse seeds. Thus, the vertebrates have plenty of food.

This study reassures us that certain ecosystem processes in tropical rainforests are considerably resistant to the human disturbance of high-intensity logging, as creatures other than invertebrates are able to perform the same functions.

However, vertebrates are increasingly under pressure from a range of human activities, so these functions are still at risk of disappearing altogether. The conservation value of logged forests is immense, as they allow us to understand how ecological processes underlying ecosystems are altered upon human intervention. ■

Stephanie Sammann is studying for a MSc in Science Media Production.

BILINGUAL BRAINS

Some are born multi-lingual, some become multi-lingual, and some remain resolutely and stubbornly monolingual. The latter obviously struggle on foreign holidays, but it turns out that they may also be intellectually and even medically worse off as a result.

The most comprehensive estimate for the number of different languages in the world is the Ethnologue which shows a surprisingly high 7,102 living languages across all countries. The sheer diversity of human language is incredible, yet the same basic aspects are shared throughout the world.

Language is the way we communicate with each other, and is used to convey messages to a listener. Of course, not all language is spoken. We can use formal sign language when communicating with those of varying degrees of hearing loss and we all exhibit unconscious body language to enhance our spoken messages. But this article concentrates on the spoken word.

When speaking, we use our mouths and throats to create a series of sounds that represent words. These words in turn mean different things and in that way the pops, clicks, and hums of our language are almost like a code between two speakers. We can decode these sounds into language so fast we don't even know we are doing it.

When children learn language, they must first learn to distinguish words from the constant stream of noises we make. Adults don't tend to pause between words as a rule, so infants learn to use statistics to pick out common sound combinations. These are cultural and vary across the world and in fact, some children never learn certain sounds not used in their native language - for example, the Spanish rolling 'r' that English lacks.

Native Japanese speakers do not differentiate between 'r' and 'l', instead using a single sound. Researchers at the University of Indiana showed in 1994 that Japanese adults could be taught to perceive the difference relatively quickly. So becoming multi-lingual can have a direct effect on the wiring of their brain, creating new connections to comprehend new sound combinations.

Children brought up in multilingual environments therefore need to learn more sounds and recognise two or more separate statistical models of noises that represent the words they need to learn. It is hardly surprising therefore that research at the Hungarian Academy of Sciences has shown that infants brought up in bilingual environments demonstrate increased problem solving ability, even before they have learned to speak. Much of our language learning is complete before we utter our first words.

> "RESEARCH SUGGESTS BILINGUAL PEOPLE HAVE BETTER COGNITIVE FUNCTION"

Further work by Kara Morgan-Short at the University of Illinois has indicated that some adults are able to pick up language through immersion, in the same way as infants, but only if they are adept at pattern recognition. It is therefore never too late to start, which is good news for the many millions of us who try to learn new languages at school or university.

In fact, there is a wide variety of research which suggests that bilingual people have better cognitive function, whenever they learned. When a person's vocabulary extends to two languages, the number of words with which to describe an object is doubled. Yet only half of those are suitable for the current situation or group of friends. That makes the brain work twice as hard to solve the problem of which words to use and when. Remarkably, the brain can achieve this without problems, but must operate with higher cognitive effort.

This increased cognitive effort causes bilingual people to be better at other real world skills such as reasoning. They have more cunning as problem solvers and more efficiency as planners. They are so used to switching between languages that moving on from one problem to another is effortless. They are better at spatial memory tasks, changing priorities and they have better concentration.

It also appears that bilingualism has medical benefits for old age too. Work by Fergus Craik at the Rotman Research Institute in Canada suggests that the increased cognitive load delays the onset of dementia by about five years, and other research shows it can also reduce the effects if and when we do begin to suffer.

All of this is pretty incredible, but there must be a downside. After all, if you ask a computer to do two tasks at once it does so, only slower. If you ask a human to do two tasks, they will do one at a time, or do both simultaneously but dreadfully. So what's the cost?

There are a couple of well-documented disadvantages of multilingualism. People who speak two languages never attain the fluency as someone who speaks only one. The brain only has room for so much vocabulary and inevitably, obscure nouns and lesser-spotted adjectives can wander from a bilingual mind.

People who speak two languages also struggle to recall certain words, twice as often as those of us who only speak one. It is as though their brains, overburdened with working out which

Being bilingual can help you on holiday, but does the evidence agree that it makes you smarter too? Ian Sillett investigates.

IMAGE: Flickr/Eric Andresen

words are appropriate, have nothing left with which to select any words at all.

Nevertheless, how often do we need to say "the expeditious, russet mammal with a reputation for cunning, vaults keenly over the somnolent canine" instead of "the quick brown fox jumps over the lazy dog"? How much of a disadvantage is it if one needs to say "urm, how do you say…" a few more times than is usual? The suggested advantages to bilingualism easily outweigh the disadvantages. But just how true is this in everyday life?

Don't take this the wrong way, there are many reasons to learn a new language. You will get fewer surprises in foreign restaurants, better job prospects and you will satisfy your cultural and intellectual curiosity. There are even proven benefits for the health of our brains in old age, and the good news is that evidence shows it doesn't matter how late you start. What you shouldn't do is assume it will make you smarter. ■

Ian Sillett is studying for an MSc in Science Communication

KEEPING PRIVATE MESSAGES PRIVATE

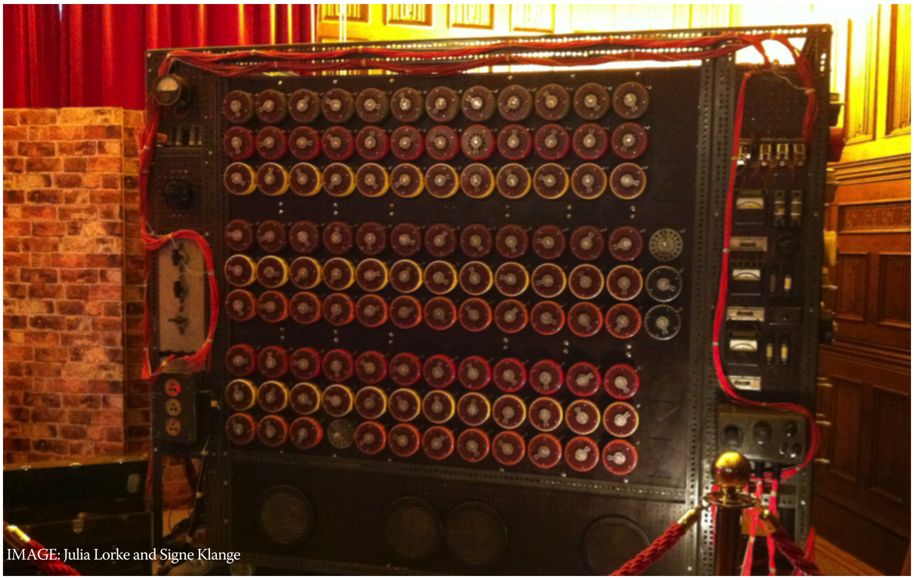


IMAGE: Julia Lorke and Signe Klange

The Bombe: the cryptanalytical machine developed at Bletchley Park


IMAGE: Julia Lorke and Signe Klange

The Enigma: a cipher machine used by German forces during WWII

Do you remember back in school when you urgently needed to share the latest gossip with your best friend during the Maths lesson? To avoid that embarrassing moment of your teacher intervening and reading out your private message in front of the whole class, you could have adapted the ancient techniques of cryptography.

The word cryptography is of Greek origin – *crypto* meaning secret or hidden and *graphein* meaning writing. Its basic principle is encrypting the original message (plaintext) by using a specific key resulting in a ciphertext. Cipher texts look like gibberish to anyone who does not have the key to decipher it. This symmetric method relies on both the sender and receiver knowing the same key to understand each other.

Julius Caesar used a simple method for his private conversations: shift ciphers, also called Caesar ciphers. This means each letter of the plain text is substituted by a letter of a fixed number after the original letter in the alphabet. Here is what the key would look like if this fixed number is three:

Plain text: ABCDEFGHIJKLMNOPQRS...
Cipher text: DEFGHIJKLMNOPQRSTUV...

A becomes D, as D is the third letter after A in the alphabet. For the message to your best friend about your new BOYFRIEND, your teacher would only be able to read out ERBIULHQG, hence, your secret stays secret. Not a big fan of Caesar? No worries, there are other traditions to follow: Mary Queen of Scots (although maybe not the most successful example), Egyptian hieroglyphs or Scandinavian runes.

How has cryptography enabled us to communicate secretly? Julia Lorke and Signe Klange investigate.

The rune alphabet - an example of alternative letters which can be used to send secret messages in school

As long as the key is unknown to outsiders, your communication is safe. If your teacher knows the rune alphabet or figures out your key for the Caesar cipher, the code is broken.

Cryptography has been used historically during wartime to prevent the enemy learning about future tactics and goals, as depicted in the recent movie The Imitation Game.

The Enigma, an impressively complex, yet elegant cryptograph used by the Germans during the Second World War, was ingenious because the code could switch infinitely. The probability of the enemy guessing the correct code by chance was 1 in 158,962,555,217,826,360,000, that's almost 159 million million million. Amazing efforts by the codebreakers at Bletchley Park, based on the work of Polish codebreakers, led to the invention of the cryptanalytical bombe machines. Combined with figuring out the human element of making errors and repetitions, which influenced the encrypting process, this led to breaking the Enigma code, a success that is said to have shortened the Second World War by two years.

Today encryption is not just used in the military. Every time we send an email, or buy an item using the internet, the message is transmitted using an insecure channel – the internet – and is therefore encrypted and decrypted using a public key encryption scheme; this happens every time the "s" in https appears in your browser. This encryption method is multi-layered and much more complex than what is described above.

The method uses asymmetric keys: here different keys are used for encryption and decryption – the public and the private key. To generate the asymmetric keys, incredibly large prime numbers **p** and **q** (each more than a hundred digits long) are generated randomly. These prime numbers are then multiplied with each other, resulting in **pq**.

> **OUR SOCIETY RELIES ON KEEPING SECRETS SECRET AND TRYING TO LISTEN IN ON RIVALS AT THE SAME TIME**

Multiplying prime numbers is easy, but figuring out which factors led to the product is quite hard. This is called a "trapdoor": a function easy to perform one way, but difficult the other way. As this is a very slow process, it is usually not used to encrypt messages, but rather to authenticate sender and receiver.

After this authentication both systems negotiate a symmetric session key that is only valid for a single communication and discarded afterwards, but allows to communicate much faster than using asymmetric keys. Such systems that combine symmetric and public-key cryptography are called hybrids. So prime numbers are the protectors of privacy.

Progress in quantum computing may be the next challenge for cryptography. In addition, the future of cryptography is largely dependent on what regulations governments put on encryptions. Prime Minister David Cameron has stated that "modern forms of communication should not be exempt from being listened to".

There seems to be a constant struggle between the public's right to privacy and government's request for surveillance as part of anti-terror and security services, called the Crypto War. Extra encryption for secure communication have emerged as a direct consequence of this, encrypting data with PGP (Pretty Good Privacy) and GnuPG (GNU Privacy Guard) helps to keep private messages private, for now.

Our society relies on keeping secrets secret and trying to listen in on rivals at the same time. From the ancient past till now, the methods have been through an arms race of secrecy, resulting in the surveillance society we have today. ■

Julia Lorke and Signe Klange are studying for MSc in Science Communication

STOPPING THE BACTERIAL SMALL TALK

Talking and teamwork – not two things you'd normally associate with bacteria. But surprisingly enough, just like us, bacteria love to collaborate, and when it comes to chattering, they're just as bad. It's this exact combination that allows bacterial populations to act as the helpful microbes in our intestines, but also the deadly infectors that have laid siege to the human race over the years. The revolutionary discovery of antibiotics in the 20th century gave us the ammunition to hold such infections at bay, but it is now clear that what we have been relying on in the past cannot be re-created here in the present.

As antibiotics have become more commonplace and accessible, overuse has allowed bacteria to fight back and develop resistance. The World Health Organisation has classified antibiotic resistance as "a serious threat [that] is no longer a prediction for the future" but that "is happening right now in every region of the world and has the potential to affect anyone, of any age, in any country". It is no surprise that researchers are frantically working to find new solutions, and rather than looking to kill bacteria, some of these involve a different strategy: stopping them talking.

LISTENING IN TO THE CHATTER

So how – and why – do bacteria talk to one another? Put simply, bacteria will only initiate an infection and cause harm to the host if their population size is big enough to evade any defences the host may have. Therefore, communication between the bacteria is vital; they need to know there is a large group of them before attacking, otherwise their attack would be futile. To be constantly pathogenic (disease-causing) or constantly harmless would be disadvantageous, which is why this on/off switch is so useful for them. By checking beforehand, they are able to save valuable resources and not waste them on what would later prove be a fruitless expedition. This process of bacterial communication is known as quorum sensing (QS).

> "THIS PROCESS OF BACTERIAL COMMUNICATION IS KNOWN AS QUORUM SENSING"

In order to communicate, bacteria release signalling molecules known as autoinducers. As well as releasing this molecule, an individual bacterial cell is also able to sense how much of the chemical is being produced in the population. The accumulation of these signalling molecules allows bacteria to sense how many of their teammates are around; if they can sense a lot of autoinducer it means their population size is large, and if not, that their population size is smaller. Bacteria are able to sense when the autoinducer reaches a certain threshold, which allows them to guarantee that there are enough of them to mount an attack. Once the threshold is reached, they are able to switch from one state to another through changes in gene expression; in pathogenic bacteria, this often means a switch from a harmless form to an infectious one.

Using this process, bacteria are able to guarantee that they will only turn deadly when they know there is strength in numbers. QS controls a number of processes within pathogenic bacteria. This includes the production of toxic and poisonous compounds, and the creation of biofilms, an impenetrable layer used to protect the bacteria from the immune system and antimicrobials. Interestingly, different species of bacteria use different signalling molecules – essentially 'speaking' in different languages.

FROM QUORUM SENSING TO QUORUM QUENCHING

Researchers believe that exploiting this perpetual chatter could allow us to prevent infection. Many scientists are focussed on developing strategies that would enable us to disrupt the QS signalling itself. By disrupting their communication, the bacteria would no longer be able to judge their population size and turn infectious, rendering them harmless to humans. Rather than the antibiotic action that aims to kill bacteria once they have launched an attack, this approach would allow us to pre-empt any assaults and disarm and disperse bacteria peacefully before they have a chance to turn deadly. Furthermore, it's thought that this method would reduce pressure on bacteria

Faiza Peeran looks at how bacteria communicate – and how scientists are exploiting this for a new generation of antibiotics.

to develop resistance, another advantage over traditional antibiotics.

Among the most dangerous bacteria today are *Staphyloccocus aureus*, the most common cause of hospital acquired infections (more commonly known as MRSA), and *Pseudomonas aeruginosa*, which often causes infections in patients with compromised immune systems. This is due to their acquired ability to resist antibiotics. But how can we stop them talking? It's thought that if we can stop the action of the autoinducers, this may stop them from being able to communicate, and therefore infect. This strategy has become known as quorum quenching.

Research into quorum quenching is widespread and varied. For example, researchers at the University of Wisconsin-Madison in the US are looking into the use of small molecule inhibitors to disrupt QS in both *S. aureus* and *P. aeroginosa*, whilst scientists at the Institute of Molecular and Cell Biology in Singapore have investigated the use of enzymes to degrade the autoinducer signals. In addition, compounds known as furanones have been shown to prevent infections by causing displacement of the *Pseudomonas'* autoinducers from their binding sites, preventing them from initiating the infection. So far, this research has shown that these methods may be successful against bacterial infection in the future.

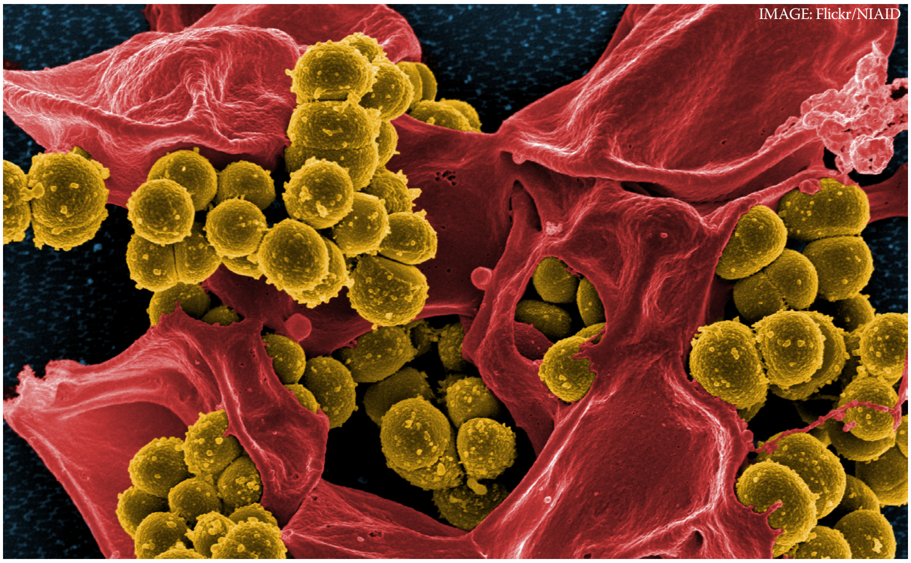
THE CHEATERS' STRATEGY

Another approach involves a slightly different take on disrupting QS. Some researchers are not only considering the bacteria's penchant for talking, but also looking into their social lives. Nearly every social group has 'cheaters' that benefit from the work of the population without contributing anything in return – essentially scrounging off their teammates. In bacteria, these cheaters thrive by ignoring QS signals and purposefully not wasting their energy making autoinducers or helping to cause disease. This gives them an advantage over the rest of the population and allows them to out-compete their more cooperative colleagues. This lowers both the population size and the severity of the infection itself, so the spread of cheats in a population can lead to a decrease in population fitness. Researchers at the University of Nottingham investigating the social behaviour of microbes (in particular in *Pseudomonas* bacteria) believe that it may be possible to exploit bacterial populations by encouraging these cheaters. They are exploring the idea of introducing thriving cheaters into an infectious population as a way of reducing disease.

A PROMISING FUTURE?

The actual degree to which these strategies could be effective is still unknown. As of yet no therapeutic drugs using these methods have been developed. However, the very discovery of bacterial communication has allowed scientists to investigate a unique mechanism among bacteria that appears ripe for exploitation. The disruption of quorum sensing looks to be an encouraging strategy that may well yield successful results in the future. Perhaps cutting short the chatter may be the answer we are looking for. ■

Faiza Peeran is studying for an MSc in Science Communication



Micrograph of Methicillin-Resistant *Staphylococcus aureus* (MRSA)

SPEEDY SCIENCE

Joanna Blackburn explains the workings of various communication systems in 150 words or less

TELEGRAPH

The electric telegraph sends electrical signals over a wire that can then be translated into a message. It works simply as a switch in a circuit. The sending end of the machine consists of a stylus with a metal tip on the end. When this is pressed it completes the circuit sending an electrical impulse to the receiver. When the receiver receives the electrical pulses it causes an electromagnet to attract a lever with an ink-covered wheel on, and the ink leaves a mark on paper. Depending on how long the stylus machine has been held down, it results in either the formation of a dot or a dash. This system is known as Morse code. The invention of the electric telegraph enabled the sending of messages over a long distance, in minutes, for the first time.

TELEPHONE

Whether you use a landline, a mobile or a telephone box, making a call uses the same simple principles. The mouthpiece contains a microphone which itself contains a piece of plastic called a diaphragm. This is attached to an iron coil and located close to a magnet. Your voice causes the diaphragm to vibrate, which makes the coil move closer to and further away from the magnet and generates an electric current. This conversion of sound energy into electrical energy makes the telephone a transducer. The electrical energy is then carried away in wires to a digital exchange that connects you to the person you are calling automatically. The loudspeaker in the phone converts the electric energy back into sound energy so your voice is heard on the other end through the same process but in reverse.

RADIO

The radio uses electromagnetic signals to send information from one place to another. The radios that you might find in your house or your car are receivers. They receive the electromagnetic waves which are sent by a radio transmitter via an antenna. The radio transmitter creates radio waves of varied frequencies and amplitude which allows the transmission of voice. Another antenna at the receiver picks up the signals and selects the range the listener has selected to hear. Radios convert these waves into audible sounds through a process called modulation. The BBC used to have a legal monopoly on radio stations in the UK. But in the 1970s, the Conservative government introduced a new bill allowing for commercial radio.


IMAGE: WikimediaCommons


IMAGE: Flickr/Plenty.r.

IMAGE: Flickr/Selby <3

TELEVISION

Cathode-ray televisions use antennas to pick up a video signal which fires a beam of electrons along a cathode-ray tube. Electromagnets steer the electrons so that it scans back and forth across the screen, 'painting' a picture over and over again. The screen is covered in chemicals called phosphors which light up red, blue or green when hit by the electron beam. By lighting up some dots and leaving some off in a very quick process, the screen can create an image. Most modern day televisions are LCD. They use pixels with red, green and blue sub-pixels that can be lit up with electricity to create an image. The brain has the ability to reconstruct these coloured dots into images and the brain interprets a fast sequence of images as moving. Over 79% of the world's population now owns a television set.

RADAR

Radar is primarily an object-detection system which can determine the range, altitude, direction, or speed of certain objects. Radar works like an echo. A signal is transmitted, bounces off of an object and is then received. The signal is created with radio and microwaves. In a radar system a transmitter sends a pulse to a switch, which causes the antenna to transmit radio waves. When the pulse has been transmitted the switch switches, allowing the antenna to receive echoed signals. The data received can be interpreted into a useful display. Radar has been successful in many areas including air travel, warfare and police speed detection. It was particularly helpful to the British in the Battle of Britain during World War Two.

INTERNET

The Internet is made up of millions of computers around the world connected in a shared network. Every computer has an Internet Protocol (IP) address which is its unique code. Every webpage has a Uniform Resource Locator (URL). Searching a URL will send your request to your Internet Service Provider (ISP), such as BT or Sky, who will use a Domain Name System (DNS) to find the URL. A DNS is a directory that finds which IP address is connected to which URL. It can then relay this information to your computer. When your IP address has connected to another it can download the webpage you searched for. In short, the DNS is used to translate from the URL to IP address. The Internet amassed 50 million users in just 5 years, a feat that took television 13 years. ■


IMAGE: Flickr/Lynn Friedman


IMAGE: PixaBay

IMAGE: PixaBay

Joanna Blackburn is studying for an MSc in Science Communication

MASTERS OF DECEPTION

Poison Dart Frog

For humans, deception is a part of everyday life. The word 'deceive' has connotations of malevolence, selfishness and strategy - deliberate lying for personal gain. We think of manipulative politicians, fraudulent businessmen or cunning criminals attempting to bend the truth at the expense of others. But often we deceive in less cynical ways, such as pretending not to see an ex in the street or feigning confidence when speaking in public. Arguably, deception is vital for self-preservation. As we learn to be more effective deceivers, we also learn to be cautious to avoid being deceived by others, resulting in a classic arms race.

Animals deceive each other with the same complexity and nuance as humans. Evidently, deception confers an evolutionary advantage. This brings up the question: to what extent is this deception intentional? Deceptive behaviours that seem deliberate may be the result of associative learning and fine-tuning by natural selection. We can look at several examples throughout the animal kingdom to try and understand their origin.

CAMOUFLAGE

In a predator-prey relationship, both parties generally benefit from remaining undetected by the other and therefore have strategies for evading detection. Some are physical, such as camouflage, which can be achieved through several means.

Cryptic colouration allows the animal to blend in with its background. This may be achieved by an active colour change, most famously seen in chameleons and cuttlefish, or through being the colour of their predominant background.

Disruptive colouration and shape scrambling serve to create a shape that does not fit the image of the prey in the predator's mind. The plains viscacha, a South American rodent, has a dark stripe which obscures its eyes, eyes being a common feature predators look for and lock onto. The leafy seadragon has a strange morphology that makes it look like floating seaweed. This means that even if it is spotted, the predator will classify it as something else. This is known as special resemblance, or 'masquerade'.

Whilst these techniques are certainly deceptive, this kind of deception is a product of evolution, not an intentional, conscious action made by the animal. Can the same be said for camouflaging behaviour?

Some animals hide from predators, others freeze to avoid motion detection, or 'play dead' so the predator doesn't pursue them. Certain moths will choose to settle on backgrounds that more closely resemble their own colouration. Are these animals consciously modifying their behaviour because they understand that the other animal may see them?

Let's use an example to explore this problem: the Grote's Bertholdia moth conceals itself from predatory brown bats by emitting high frequency clicks of up to 4,500 per second to jam echolocation - a unique defensive adaptation that is extraordinarily similar to radar jamming techniques used by the military. Does the moth know that it is jamming the bat's echolocation and therefore giving itself a fighting chance at escaping? Has it learned to click when in the presence of a brown bat? Or has

Madeleine Hurry uncovers the world of deceptive communication in the animal kingdom.

natural selection resulted in this automatic, reflexive behaviour?

DEFENSIVE ADVERTISEMENT & MIMICRY

Instead of avoiding detection, some animals are confusingly conspicuous, such as brightly coloured poison dart frogs. They advertise that they are unpalatable, dangerous, and that the predator will suffer some sort of cost by choosing to eat them. This is called aposematism.

Some animals will display the aposematic warning signal, but lack the dangerous feature. These animals are known as Batesian mimics and essentially deceive the predator by making it think they are dangerous, for example hoverflies that are harmless but look like wasps or bees. In a similar way, the bright leaves of the venus fly trap attract insects which mistake it for a nectar-bearing plant. It feigns harmlessness whilst actually being deadly; this is known as aggressive mimicry.

Again, this kind of deception is not intentional. Let's look at a situation where an animal modifies its behaviour in order to mislead another.

KILLDEER DECOYS

When a predator is in close proximity to a nest, a parent Killdeer bird will feign having a broken wing and hop around in front the predator, so as to divert its attention from the nest and protect its offspring. Despite not actually being injured, the behaviour is so convincing she is often successful. This behaviour is flexible, in that if the fox returns to pursuing the nest, the broken wing behaviour will intensify.

Whilst effective, it is hard to tell whether the bird is intending to deceive the fox, i.e. whether she knows that the fox will interpret the wrong signal, or if she has adopted this behaviour because when she did it in the past, it protected her young. The latter explanation relies on associative learning, which does not require higher level cognition. Alternatively, the behaviour could be a reflexive response which has been created by many years of natural selection.

> **"ANIMALS DECEIVE EACH OTHER WITH THE SAME COMPLEXITY AND NUANCE AS HUMANS"**

COMPETITIVE CHIMPS

An experiment looking at chimpanzee behaviour in a competitive feeding paradigm provided interesting results. A dominant and subordinate chimp would be placed on either side of a feeding cage and food was "hidden" inside. Two conditions were applied: (1) food was placed where both chimps could see it, and (2) some food was placed where only subordinate could see it, and other food placed where both could see it. In the second condition, subordinates would go to the food hidden from the dominant in 73% of trials, therefore avoiding conflict and obtaining more food. It seems that the subordinate is aware the dominant can't see the hidden food. But perhaps the subordinate was simply monitoring the dominants behaviour and chose to go to the hidden food when it saw the dominant approaching the open food.

SCROUNGING SCRUB JAYS

Wild scrub jays hide food and store it for later (caching). Sometimes jays will pilfer the stores of others – a deceptive act. It was noticed that sometimes jays would re-cache their own food in a different location. This happened more frequently when they had originally hidden food in front of others. Perhaps they understand that if others can see where they are hiding food, they may steal it, and thus are protecting themselves from pilferers. To test this idea, two groups of hand-reared jays were allowed to cache food in the presence of others. One group had never pilfered; the other frequently did so. It was found that the only the pilfering group recached their food. Does this suggest that they have insight into their own actions and can project this experience onto others? In other words, are the pilferers self-aware, such that they understand that their food may be pilfered by other deceitful individuals?

Perhaps. This study is promising, but it needs replicating. It is still possible that a behaviour reading artefact is at play: suspicious subjects may cause differences in observer behaviour to which they react. This illustrates the difficulty of distinguishing between cognitive and sophisticated behaviouristic explanations!

INTENTIONALITY IS HARD TO PROVE

Trying to deconstruct the cognition behind animal behaviour is extremely challenging, in the same way that testing for consciousness is. Nonetheless, the field is fascinating and a reminder not to attribute humanistic explanations to the rest of the natural world. ■

Madeleine Hurry is an MRes Student studying Experimental Neuroscience

SCIENCE BEHIND THE PHOTO

Image and words by Sarah Worsley

Getting yourself noticed can be a challenge in nature but can play a vital role in tasks such as mate attraction, conspecific recognition and rival deterrence. This male Amazonian Royal Flycatcher, pictured in the rainforests of Guyana, raises his vivid crest in an attempt to capture the attention of passing females but also during aggressive interactions with competing males. The elaborate headdress is just one example of a visual signal designed specifically to communicate information to a chosen receiver.

A good communicative signal, whether it be visual or of another kind, needs to be both effectively transmitted and perceived by the desired recipient. At the same time it is crucial to avoid unwanted attention from potential eavesdroppers such as predators. Variation in the structure of different habitats can have a large impact upon which signal designs meet these requirements.

Light is one aspect of the environment that is particularly important in influencing the evolution of visual signals. The intensity and spectral composition of absorbed and reflected light varies, meaning that certain signals are likely to be more conspicuous than others in a given location.

In the rainforest understory, dense vegetation results in a background of reflected green and brown light. In many understory birds, such as the flycatcher, visual signals have evolved to contrast sharply with this backdrop. Their feathers contain pigments such as carotenoids that reflect light in the orange-red part of the electromagnetic spectrum. Displaying this plumage in sun-flecks can further increase their conspicuousness whereas, in shade, the lower intensity of these wavelengths helps to reduce detection by predators.

A number of birds also display and detect UV signals, particularly in the canopy where there is a high intensity of radiation at these wavelengths. Such signals previously remained hidden due to the inability of the human eye to detect UV. However, it is now clear that several groups of organisms may exploit these signals, including bees and several species of fish. These findings open up the possibility that a whole array of exciting but, as yet, secret communication channels, unused by humans, may already exist in nature.■

Sarah Worsley is studying for an MSc in Ecology, Evolution and Conservation

INITIATING LABOUR

Syed Asaad Qadri explains the complex internal communication of giving birth.

As mothers everywhere will tell you, labour is definitely no easy feat. Every experience is different, and depending on the type of pregnancy, the duration of labour can vary between 2 and 18 hours. After nine months of pregnancy, the wait is finally over and the human body readies itself for the delivery of a new life. But how does the body prepare for such an undertaking? The communication between the mother and foetus's body, along with various molecules and chemicals turns out to be key in initiating this process.

> **"LABOUR INVOLVES COMPLEX COMMUNICATION BETWEEN THE PLACENTA, FOETAL LUNGS AND MOTHER'S UTERUS"**

Labour is initiated through a change in the uterus from what is known as an anti-inflammatory state to a pro-inflammatory state. This essentially means that the body harnesses the power of the immune system during labour and causes of the release of certain molecules and chemicals. This switch to turn on the immune system is caused by the activation of an important gene complex known as NFkB. Human labour involves complex communication between the placenta, foetal lungs, foetal membranes and the mother's uterus – which are all geared towards activating NFkB. The question is – what starts it all off?

The foetus must communicate its stage of development to the mother in order to initiate labour. The baby's lungs are one of the last organs to develop, and as they reach the final stages of maturity, they secrete pulmonary surfactant, a detergent-like agent, which prevents lungs from collapsing during exhalation. Studies on mice have shown that a component of this surfactant helps to promote labour by up-regulating NFkB and other pro-inflammatory molecules in the mother's uterus and triggering contractions. In fact, one of these pro-inflammatory molecules (known as prostaglandin) can be used in the form of a gel to induce labour in some mothers that have gone past their due date, or who have developed potentially threatening conditions such as pre-eclampsia.

The muscle layer within the mother's uterus is known as the myometrium. During pregnancy, this muscle lies dormant. During delivery however, the contraction of the muscle becomes essential. Muscle contractions rely on electrical impulses that spread through them – and the propagation of these impulses is only achieved by proteins on the surface of the cell known as gap junctions. These gap junctions, whilst normally absent, are widely expressed during the late phase of pregnancy – a single muscle cell can express over 1,000 copies. It is these proteins that are the gatekeepers of communication between the foetus and the mother's uterus.

However, it is important that this muscle does not contract prematurely and cause early contractions. A hormone known as CRH (corticotropin releasing hormone) is released to prevent this from occurring – the production of which is controlled by the placenta.

Hormones are key to the process of labour, so it is not a surprise that the pregnant mother is a specimen of hormonal firepower. Fluctuating hormones – such as the reduction of progesterone and the increase in oestrogen – signal the oncoming of labour itself. Another hormone, oxytocin, is known as the bonding hormone. Its levels stay constant throughout pregnancy. However, in labour, the oxytocin receptor (that binds to oxytocin) increases hugely. This means that oxytocin is able to bind to its receptor, induce the creation of prostaglandin and initiate muscle contraction in the uterus.

Understanding how labour initiates in humans has proved almost impossible due to the obvious ethical issues surrounding human foetal experimentation. Sadly, premature labour affects about 10% of pregnancies and is common in pregnancy related diseases such as pre-eclampsia and intra-amniotic infection. The prize for unravelling the complex initiating mechanism of labour is the potential to help prevent premature birth, which is the most common cause of neonatal death worldwide. Whilst the intricacies of the labour process are a fascinating topic, perhaps it's best not to mention these to a mother in labour – our best bet is she won't be thanking you for your insight! ■

Syed Asaad Qadri is studying for an MSc in Reproductive and Developmental Biology

IMAGE: Flickr/Cary and Kacey Jordan

DOWN BUT NOT OUT

A nightmare which becomes reality for some. Lizzie Norris investigates some of the technologies used by doctors to predict patient consciousness and survival following brain injury.

Geoffrey lay in a hospital bed; unable to move or speak, and yet was able to understand everything being said around him. Even on hearing his fate being discussed, he was unable to respond. It seems the stuff of nightmares, but it may be a reality for many comatose patients.

Geoffrey Lean is a journalist who has written about his experience. He fell into a coma for one month after a routine operation went disastrously wrong. Geoffrey recalls being very aware of his surroundings; conversations around him, the news broadcasts, and could repeat anecdotes about things said to his apparently deaf ears. Research over the last few years has demonstrated that many comatose patients may experience something similar which raises questions about how much we actually understand about the brain when patients are in a coma or vegetative state.

The brain is the ultimate communication tool. In the form of chemical messages, nerve impulses and hormones, the brain is responsible for sending and receiving millions of signals every second, making us move, think, eat and sleep. The normal functioning of the brain can be impaired or lost by traumatic injury such as a blow to the head, or acquired injury at a cellular level.

A coma is a consequence of brain swelling and is one of the signs of brain trauma patients can experience. Patients in comatose states are unable to show signs of response to stimuli such as pain or sound, such as when a close relative calls their name. Without communication with the patient, it can be difficult for doctors to determine the extent of their coma and brain trauma.

To assess the coma level of patients, doctors use two different scales: The Glasgow Coma Scale and the Los Amigos Scale. These scales both focus on the patient's responses to certain stimuli, responses can include eye opening, motor responses and verbal responses, as it is common for coma patients to make sounds.

While many patients recover from a comatose state, it is no indication that they will be left without further brain damage. MRI and CAT/CT scans are used to measure the anatomy of the brain and can identify structure deviations such as tumours, haemorrhages and blood clots. Obvious defects such as these can sometimes provide an indication of whether the patient is likely to make a full recovery.

Methods such as Positron Emission Tomography (PET) are used to measure the activity in the brain by using the emission of positrons following a small injection of radioactive isotope. The result is a 2D map which can potentially diagnose areas affected by strokes, cardiovascular disease and changes in activity.

Other frequently used techniques include Electroenchephalography (EEG) which works by measuring the fluctuations in voltage that result from ionic current flows between neurons in the brain. It can be used to diagnose patients with seizures, tumours, head injuries, degenerative diseases and even brain death.

"A COMA IS A CONSEQUENCE OF BRAIN SWELLING"

These methods can tell us a lot about the functionality of the brain but cannot always determine the outcome for patients, nor provide clues to patients such as Geoffrey's levels of awareness while in a coma.

One technique that stands out is the London Hospital Survival predictor, devised in 1972,

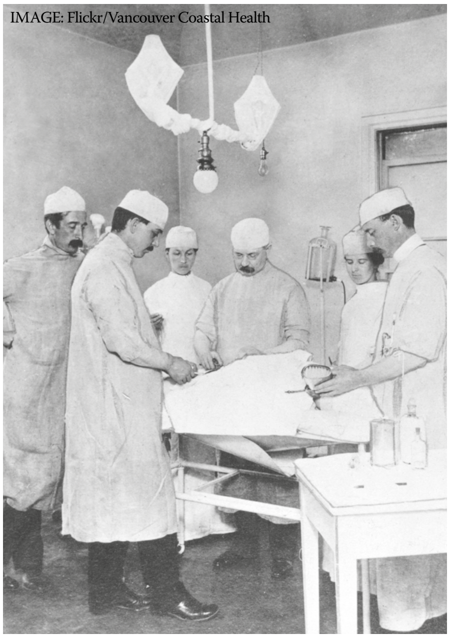


IMAGE: Flickr/Vancouver Coastal Health

used for predicting whether patients in comas resulting from heart attacks would recover. A box with a single dial, if the needle swings one way, it points to one word, 'survive,' and the other to 'IBD' (irreversible brain damage leading to death). The software was taught which EEG features indicated a more or less favourable outcome, using data from patients who had either died or completely recovered.

The device was never actually used to determine whether life support should be withdrawn and staff were aware of its potential for misinterpretation. However from Geoffrey's story alone, it is frighteningly clear how much is still unknown about the awareness of comatose patients and those with other brain trauma symptoms. ■

Lizzie Norris is studying for a PhD in Advanced Chracterisation of Materials

LIFE IN TECHNICOLOUR

Anne Petzold investigates how the brain allows us to see in colour.

Colours are produced by different wavelengths of light, usually reflected off the surfaces of everything around us. How does our brain turn these wavelength signals into the sensation we call colour?

STAGES OF COLOUR PROCESSING

Our retinas contain two types of light-sensitive cells: rods and cones. The cells that respond to colour are cones, and we have three different cone subtypes that respond to light of short ("blue"), middle ("green"), or long ("red") wavelengths. But models suggest that humans can distinguish between up to 10 million different colours. With our limited number of photoreceptors, the secret lies in the way we compare their answers relative to each other.

For colour processing, the primary visual cortex contains colonies of cells organised in columns called "blobs". These double-opponent cells compare red-green and blue-yellow ratios of the photoreceptor input. This information is passed on to secondary visual areas where other cells, "globs", extract the full range of hues that make up our colour space. Injury of these areas can result in colour agnosia - the complete inability to perceive colours.

Information from secondary visual areas is then passed onto the inferior temporal cortex (just behind the temples), where colour information is integrated with other visual dimensions such as shape.

Colour processing along this axis is integral to the "ventral pathway" of visual perception, which is dedicated to "what" we see, while the "dorsal pathway" is thought to be concerned more with the "where" dimension of vision, such as motion.

The target of the "what" pathway, the temporal cortex, is also crucial for the formation of multidimensional long-term memories, including explicit information of objects and their context. The "where" pathway, however, aims for the side regions of the brain, the parietal lobes, and is connected to motor areas. Gender might affect the relative priority these pathways are given: women seem to be better at distinguishing small differences in colour, while men do better at tracking fast moving objects.

Processing different dimensions of objects, such as colour, shape and motion, at different stages and even in separate pathways has curious consequences. Imagine trying to find the largest Easter egg in your Easter hunt basket - a tedious task. Trying to find the red egg among the yellow ones, however, will not take more than a split second, as colour is processed much faster than shape. We'll be sure to catch the green egg that is rolling off the table, as the "where" pathway that processes motion directly connects with motor areas, enabling us to notice a falling egg and catch it in the blink of an eye.

I CALL IT BLUES...THE LINGUISTIC RELATIVITY OF COLOUR NAMING

Considering that the internet community is divided about the colour of an evening dress pictured on Tumblr, colour perception may be a product less of the early hardwired stages of colour processing and much more of their environmental context and the way we communicate colours among each other.

For instance, Russian draws an obligatory distinction between lighter blues ("goluboy") and darker blues ("siniy"). In a respective colour discrimination task designed by Lera Boroditsky this linguistic dog-ear gave Russians an advantage in telling blues apart compared to English speakers, but only as long as their language capacities were not overloaded by a competing verbal task - proving the point that Russians had a specifically verbal advantage due to additional colour names.

COLOUR PERCEPTION THROUGH CONTEXT

In the most marvellous sunset the beach will appear light yellow, not orange, even though the light reflected off the beach would be in the orange range of the light spectrum. Why do we see the same colour under such different conditions? Why does the colour we see not always match the wavelength of light reaching our eyes? This phenomenon is called colour constancy and is a bit of a mystery to colour vision researchers, although there are several different theories. The double-opponent cells in the "blob" columns of the primary visual areas compute the relative difference between cone signals to calculate the wavelength reflected by an object within the composition of illumination in the whole scene. We actually use several cues to achieve colour constancy, largely comparing an object within its wider context, including not only space, but also time. Thus, colour constancy only works in context: if we could focus on a little patch of beach and exclude the illumination from the rest of the scene, the beach would have the colour of an orange.

Colour is not an inherent and inflexible property of light itself, but a result of the particular visual perception of the particular observer in a particular context and a particular set of experiences.

So do we all see the same colour? Do the different colour names and categories across languages change colour perception? These are questions about how we remember colour from one situation to the next, and how we communicate colour among each other, and these belong to another chapter of colour perception: psychology of perception.■

Anne Petzold is a second year PhD student studying Neuroscience

MASTERS OF SEDUCTION

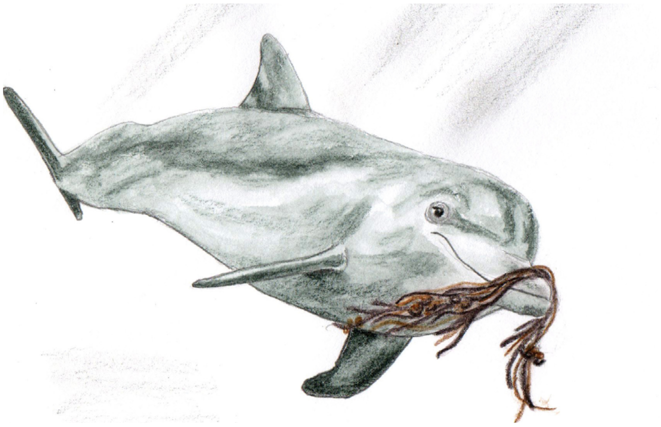
Emily Mobley explores some of the extraordinary courtship rituals that take place in the animal kingdom.

Illustrations by Kate Whittington

In nature, the competition to win a partner can be so intense that it creates both extraordinary beauty and bizarre courtship behaviours. Success in nature is all about creating the next generation, and various males do whatever it takes to communicate their fitness and win over choosy females.

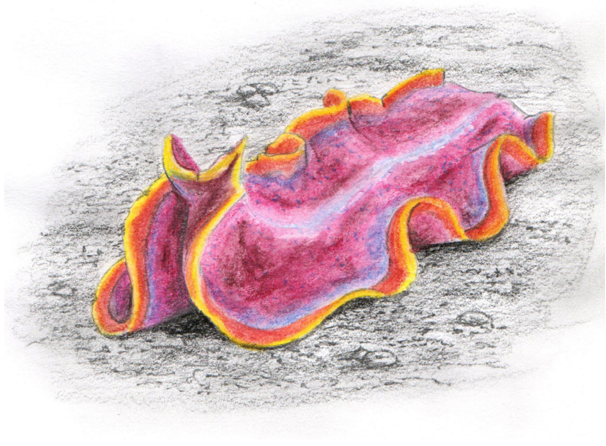
FEATHERED WING MAN

A male long-tailed manikin bird has the task of trying to impress one of the world's choosiest females. He has been practicing his moves for nearly a decade in the Costa Rican jungle, and is joined by another male – not a rival but his junior partner. The master and apprentice co-ordinate their courtship dance routine and know each other so well that they can finish each other's calls. The female expects perfect harmony so they must practice together every day. She is a dull green colour, in contrast to their black plumage with blue back feathers, red caps and long tails. To court her the males dance in synchrony, jumping up into the air, swapping positions and harmonising their calls. When they win her over the apprentice is banished and only the master gets to mate; there is no reward for the apprentice until his master dies and he can take his place.



SAY IT WITH FLOWERS

The BBC series Spy in the Pod gave a turtle's-eye view into the courtship behaviour of bottle nosed dolphins. In the breeding season, young males swim together in bachelor pods seeking out pods of females. To impress a female, the male dolphin will spend hours searching for the perfect strand of seaweed which he then tosses around in the water to show off his agility, before presenting it to her like a bunch of flowers.



MAKE WAR NOT LOVE

Whilst brightly coloured marine flatworms may look graceful as they glide through the water, for them the mating game is a battlefield. Marine flatworms are hermaphrodites, and possess both male and female sex organs. When mating, the flatworms must decide who takes on the more costly maternal role in reproduction. The negotiation takes the form of 'penis fencing', a type of combat during which the two flatworms rear up and expose their penises to try and stab each other. The two flatworms fight it out for up to an hour until the 'loser' is inseminated, and must take on the role of the female in producing offspring.

MY SPOTS ARE UP HERE

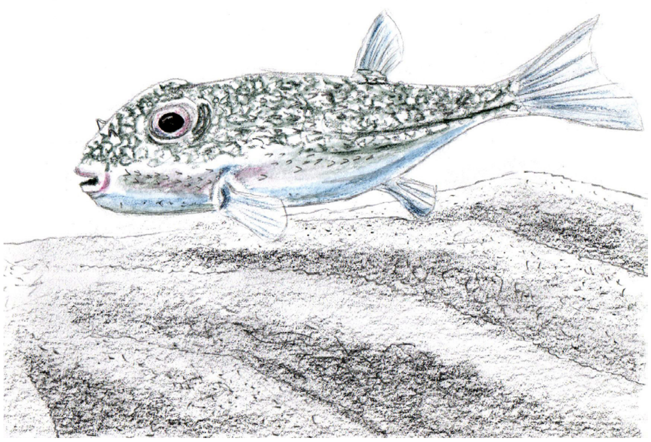
In one of the most renowned displays of animal courtship, male peacocks show off a brilliant array of feathers which make up a five foot tall tail, dotted with brightly coloured eye spots. The choosiness of peahens has driven the evolution of this giant tail in males, which acts as a sexual handicap in that it makes him more vulnerable to predators but more sexy to females.

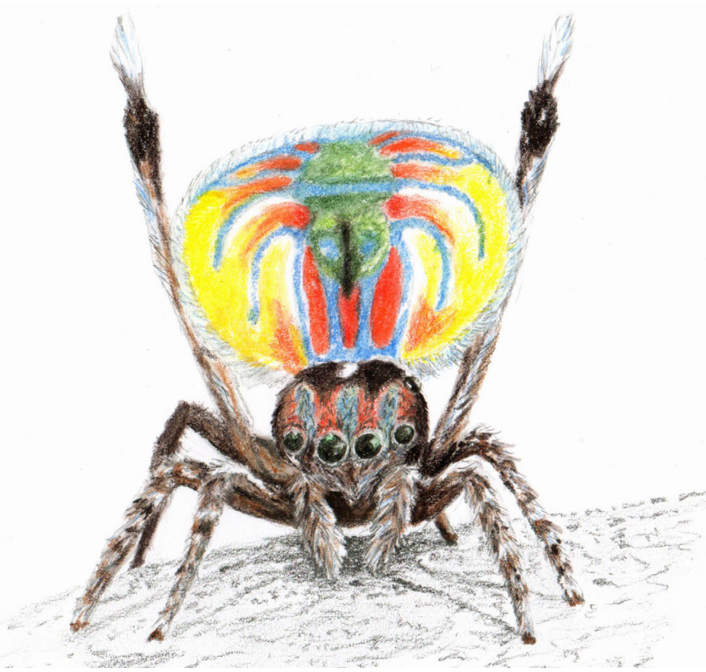
However, studies have shown that perhaps peahens aren't so interested in the elaborate tail, but more the courtship dance. Using eye-tracking technology, researchers found that peahens pay more attention to the male's legs and the lowest edge of the tail feathers; she rarely gazes into his eyes – neither those on his head or in his tail. In particular, when he turns his back and rustles his little white tail feathers in the dance she is the most attentive. Therefore it may be that size doesn't matter when it comes to peacock's tails, but more how he uses it in his dance moves.

THE ARTIST

At the bottom of a bay in Japan, a small grey Japanese pufferfish is almost invisible on the ocean floor, so to attract a female's attention he has become one of nature's greatest artists. Using his fins as his only tools, he follows a plan of mathematical perfection in his head and ploughs the sand, breaking it up into fine particles. He removes shells and uses them to decorate the peaks of his masterpiece, which he must work on 24 hours a day for a week to protect it from the ocean currents. The result is an astonishing, geometrical crop circle in the sand.

A female, bulging with eggs comes to inspect his creation before leaving to await the final stage. By the next morning the male has moved all of the softest sand to the middle, creating a soft bed ready for her eggs. When she lays her eggs in the heap of sand, the male grasps her cheek with his beak and fertilises them, before flicking his tail to bury the eggs. After an hour of rough affection, which leaves a love bite on her cheek, she finishes laying her eggs and leaves the male to stay and fan the eggs until they hatch.





DEADLY FIRST DANCE

For a male peacock jumping spider who's only the size of a grain of rice, almost anything can be dangerous – but most of all, a potential mate. In Australia, the male spider seeks out a female by following a scented strand of her silk. Along the way he encounters previous victims of similar endeavours; the female is not amorous, and kills every male that doesn't match her expectations. However, his argentine tango may win her over. When he meets the female, a complicated dance routine commences. He waves his third legs in the air and raises his brightly coloured abdominal flap, like a peacock's tail, attempting to seduce her. Meanwhile she attacks him continuously. Finally she succumbs and allows him to mate with her, then kills him anyway – after all his body makes the perfect meal to nourish her eggs. ■

THE STAGE IS SET

In the forests of Papua New Guinea, a bright yellow bird with a red hood creates a stage. The flame bower bird possesses an eye for detail as he builds a bower out of twigs, before painting it with mud to create a darker background to set off his magnificent plumage. He spends a week building and dressing the set with leaves, bright blue berries and flowers, before he calls for a female and waits.

When a female visits, he lures her into the bower before he starts the show. First he mesmerises her by dilating his pupils alternately, then limbers up by stretching out his wings and letting out a wheezy call from deep in his throat. During his grand performance he looks over his shoulder and waves his wing like it's a matador's cape, vibrating his body up and down. She gives him a hint by picking up a blue berry, which he uses as a prop in his dance. When she's really interested, he gets physical and head butts her chest.

Emily Mobley is studying for an MSc in Science Communication

SUPERLUMINAL

WE'RE TALKING FASTER


IMAGE: Flickr/Sweetie187

Light travels extremely fast – in less than a second, it could travel seven times the circumference of the Earth. Most of our communication systems use light or other electromagnetic waves to send messages, which means we can talk to others on the far side of the world in almost no time at all. It's difficult to imagine that, on Earth, we would ever need anything faster.

However, space is big: sending a message to Mars using light would take 12.5 minutes, resulting in a very jolted conversation. Sending a message to the nearest star beyond our Sun would take no less than four years. If superluminal communication (communication faster than light) were possible, it would open up doors for how we might communicate with deep space explorers in the future.

Looking at whether superluminal communication is possible takes us on a whirlwind tour around some of the most exciting places in physics, from space-warped wormholes to particles that can travel backwards in time. We begin, though, in the bizarre world of quantum mechanics.

QUANTUM ENTANGLEMENT

Some of the strangest phenomena in science are described by the theory of quantum mechanics, a theory that was developed in the 1930s and has received great experimental support since. One of the strangest phenomena is known as 'quantum entanglement,' which appears to allow quantum particles to communicate with each other at more than 10,000 times the speed of light.

Entanglement occurs when two particles are linked to each other in such a way that they behave as one and the same entity. Entangled particles can be created quite easily in the laboratory with the right equipment. Particles have a property called 'spin,' and a particle's spin can be either up or down. Quantum mechanics tells us that two particles that are entangled don't have a definite spin until their spin is actually measured. This means that the act of measuring the particle actually changes the state it is in.

This is bizarre enough, but here is the crux: for entangled particles, the act of measuring one particle doesn't just change the state that particle is in, but also changes the state of the other particle. If the first particle's spin was measured, and found to be up, the second particle's spin would then change from being indefinite to being down. What is especially striking is that, according to quantum mechanics, the particles have this influence on each other however far apart they are, even if they are on opposite sides of the universe. Since the 1980s, experiments have been performed demonstrating this phenomenon, with more recent experiments showing that the influence is taking place at least at 10,000 times the speed of light.

If quantum entanglement could be exploited to send messages, it would mean big things for

COMMUNICATION: THAN LIGHT

Kruti Shrotri questions whether we'll ever be able to communicate faster than the speed of light.

superluminal communication. Unfortunately, however, it has been proved that quantum entanglement cannot be used to send messages superluminally, and that nor can it be used to send any kinds of messages at all. This law is known as the 'no signaling theorem'. Its proof essentially shows that, despite the link between two entangled particles, there is nothing that one person can do to one entangled particle that would be detectable by another person with the other entangled particle.

WARPED SPACETIME AND WORMHOLES

Our next stop takes us to the theory of general relativity, into the very fabric of the universe. Because of the three spatial dimensions and one temporal dimension that makes up our universe, we call this fabric 'spacetime'. The idea of a wormhole, first introduced in the 1920s, is based on the thought that spacetime can be warped, providing a shortcut between two distant points in the universe. To conceptualise how this might work, image that two distant points in the universe are represented by two ends of a long thin rubber tube. The rubber tube itself represents the distance between these two points. However, if you curl (or 'warp') the tube so that the two ends meet, you have created a shortcut for getting from one point to the other.

If such wormholes do exist, it might be possible to use them to send messages from one point in spacetime to another. Though the message would not actually be travelling superluminally, it would certainly appear to be. However, though the theory of general relativity, which is currently our best theory of how spacetime works, does not deem them impossible, no evidence of wormholes has yet been found. Moreover, even if they did exist, it would be serious challenge to use them to send messages: they would be extremely unstable and sending a signal through it might cause it to collapse.

MOVING FASTER THAN LIGHT

What if we could communicate superluminally simply by speeding up the signals that carry our messages so they go faster than the speed of light? Unfortunately, as the theory of special relativity tells us, this is not possible. The speed of light in any given medium is always constant. This means that we cannot speed up the light or other electromagnetic waves that carry our messages.

> "IF TACHYONS DO EXIST, THEY ACTUALLY MOVE BACKWARDS IN TIME"

Nor can we get a different particle, one with mass, to speed up enough to cross the barrier of the speed of light and move superluminally. Special relativity shows that the more energy you give a particle with mass, the heavier it gets; and subsequently, the harder it is to speed it up. In fact, it would take an infinite amount of energy to make a particle with mass travel at the speed of light. As we could never harness an infinite amount of energy, getting a particle to cross the speed of light is definitely a no-go.

But what about a particle that always moves superluminally? Though special relativity excludes the possibility of a particle crossing the speed of light, it has no qualms about a particle that permanently moves at more than the speed of light. Such particles were first hypothesized in the 1960s, and are called 'tachyons'. Though tachyons have never been detected, their existence has not been ruled out either.

If tachyons do exist, they have many strange properties: to start with, their mass, derived from taking the square root of a negative number, is mathematically 'imaginary'. Furthermore, they have negative energy: in fact, the less energy a tachyon has, the faster it moves and a tachyon with no energy moves infinitely fast. To top it all off, tachyons can actually move backwards in time.

Incorporating such characteristics into a coherent theory is something of a challenge (how can something have an imaginary mass?). But if tachyons could be used to send messages, perhaps the biggest challenge of all would be dealing with the paradoxes that arise. Consider this: suppose that Alice sends Bob a message at midday using tachyons, which, since tachyons can move backwards in time, Bob receives at 11am. The message to Bob reads: "Send Alice a message telling her to not contact you anymore". So, at 11am, Bob sends Alice a message using tachyons, telling her to not contact him anymore, which Alice receives at 10am. Then from 10am, Alice stops all contact with Bob. So, because of the message she sends at midday, she will no longer send that message at midday. Thus arises the paradox.

It seems unlikely that we will be able to have superluminal communication in the future, because the potential avenues that may lead to it are riddled with theoretical impossibilities. However, these avenues take us through some of the most interesting areas of physics that explore the fundamental nature of our universe, where there is still so much more to learn. So, never say never. ■

Kruti Shrotri is studying for an MSc in Science Communication

INTERVIEW GARETH

***I,Science* Editors, Iona, Jen and Kruti, went to ask Gareth Mitchell about being a science communicator. Here's what they found...**

Firstly, tell us a bit about what you do?

As a science communicator I do three main things. The first is teaching science communication at Imperial College in which I teach radio journalism and small amount of written journalism. The second is presenting a technology programme on the BBC World Service, a radio show called 'Click'. The third, which is relatively small, is writing for *Focus* magazine as a so-called expert on technology Q&A pages.

Which of those is your favourite?

Funnily enough, my favourite is the thing that I'm not doing at the time. So if I'm at the BBC, then it makes me miss being at Imperial College because you're in the cut and thrust of the broadcast environment and you miss the more reflective and thoughtful feel and culture of being in the academic world. But then when I'm in the more reflective academic world, I slightly miss being at the BBC, where it all happens.

How did you end up as a science communicator?

So for me my path into science communication started here at Imperial College, studying the Science Communication MSc, many years ago. I did a work placement as part of my course in the science unit of BBC world service radio. Then when the work experience ended I refused to leave and became a freelance reporter, just doing short interviews at first, and then more constructed features - packages as we call them - and then finally moving into presenting. On the way I also did just less than a year at Radio Netherlands, the Dutch international radio service, producing and presenting a science programme in English.

What do you think is the hardest thing about your radio programme, 'Click'?

I think the hardest thing about doing the weekly cut and thrust of a radio programme is just that it is every week! So as soon as the programme is finished then we're already thinking about the following week's programme. Every week there are three or four interviews to do and every week there's a script to write. I feel as if I ought to put 110% into it every time, and treat it as if it's my first programme, even though I've done many.

Do you ever get a week off?

I don't, which makes me in some ways very unlucky, but ultimately very lucky - especially because I am paid per programme. Most freelance presenters would be very envious of a 52 week a year commission on the programme! If I do go away then we usually pre-record the programmes instead. I genuinely like it like that, partly because I'm very protective about the programme - I don't want anybody else to do it, even if it means I have to work really hard for two weeks before I go away.

Why to you is science communication important?

I think it is important for people to tell the outside world what's going on in the world of science - we live in a knowledge economy! And I also think it's important for scientists themselves to be science communicators because, in the vast majority of cases, they are funded ultimately through central taxation. I also think that a culturally literate population is generally a happier, healthier, more sceptical, prosperous population. And it keeps people like me in a job. That's a very important reason too!

Are scientists any good themselves at science communication, or do you think science communicators are necessary?

I suppose I would say this, but I genuinely believe there's room for both. The science communicator is the mediator between the audience and the scientist - scientists are busy people. They haven't got all day to sit around

WITH MITCHELL

worrying about how to communicate what they do. So, if there are people who do worry about that, then that's great.

Whether scientists are good communicators? I think the good news is that they have got a lot better. And having been doing broadcast and a small amount of written journalism for the best part of 20 years, I can definitely say that from experience - when I first started, it was often a real struggle to get a scientist to agree to give you an interview, and if they did give you an interview, the chances were that it was going to be hard work and you'd have to tell them loads of times to make it more accessible. These days, scientists hardly ever say no to giving an interview, and most of the time they turn up and do a great job.

What is a good quality in a scientist as a communicator?

A good scientist communicator is somebody who understands their audiences - who understands that the message they might give to a grant giving body might be different to one that they would deliver as a sound bite on a radio programme, which in turn might be different to the mode of communication to school children. I think this is a huge challenge. I really admire scientists who can navigate those audiences so effectively.

Do you have a favourite science communicator?

Obviously I won't say Brian Cox and David Attenborough, because everyone says them, good though they are. But, for instance, Jonathan Amos - Jonathan is a science correspondent online at the BBC and I've worked with him on programmes where he just needs to come in as live and explain what's going on in a big science story this week in 47 seconds - he always nails it. And Bill Thompson who is on 'Click' with me every week. People like Bill and Jonathan can just communicate a message, put it into context and be independent and critical of it - and all those thing to a very defined time on air! Away from the broadcast environment - I've always been a fan of Greg Foot - I've always enjoyed his rather irreverent attitude to communicating science and the energy and originality he brings to it. He's young, energetic and fresh.

What is your most embarrassing moment on live radio?

Occasionally we do our radio programme at BBC's radio theatre as a live audience programme, and I think my most embarrassing moment was a when really expensive robot just fell off the stage! The scientist had just made clear that the whole point of this robot was that it was really good at judging space and distance. But it just didn't see the end of the stage and it fell off! The audience went crazy laughing... Probably more embarrassing for the robot than for me, but as the person hosting I just had no idea what to do, so I just stood there, I froze. I would love to say I picked it up perfectly or came up with a really amazing pithy joke, but I completely panicked. I was just crushed with embarrassment for myself, for the scientist and for the robot.

Last words of wisdom to all the Imperial scientists out there?

To Imperial scientists my advice would be to just get out there and communicate – do not fear it! And yes, there are definitely dangers, like with anything in life, if you put your head above the parapet things can go wrong: you could speak to the media and get misrepresented, or you might host a science event and people might not turn up and things might blow up, but you won't know if you don't try. The potential opportunities and the social good that comes from you getting out there are great– the benefits from that far outweigh the inevitable risks. And it's great fun - what could be better than telling other people about the work you love? So go out and do it! ■

You can listen to Gareth's radio programme 'Click' on BBC World Service at 6.30pm every Tuesday evening.

THE GREAT DEBATE

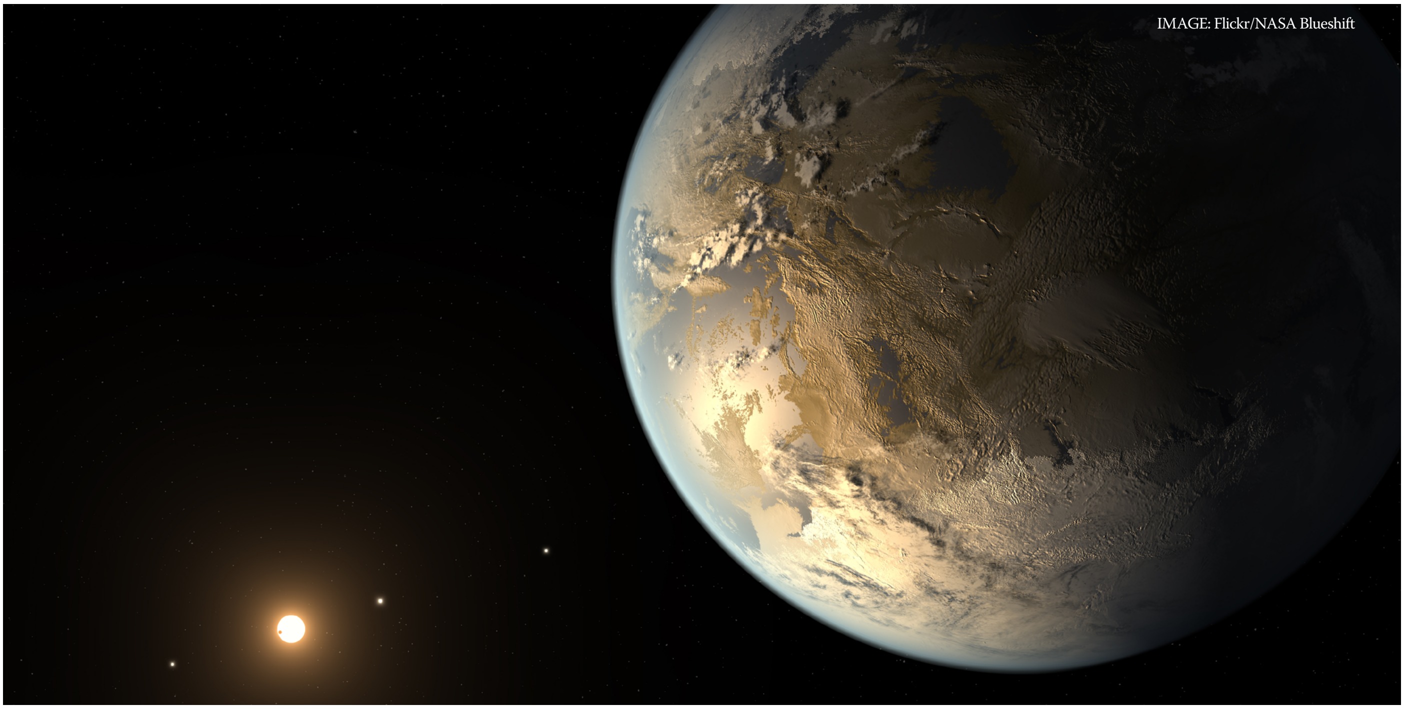


IMAGE: Flickr/NASA Blueshift

There are likely to be millions, if not billions, of habitable planets out there. This is Kelper 186f discovered by Nasa last year

Whilst the opinion of many in the scientific community is that as a species we should keep quiet and alien contact should not be made, I feel that this is not only the wrong decision, but also futile in reality. Alien societies capable of even contacting, yet alone visiting Earth would be immeasurably more technologically advanced than ourselves. In short, they would possess the knowledge and capacity to identify planets suitable for habitation or resource harvesting with a much greater degree of accuracy and precision than our own existing technologies allow for. With the Earth being such an excellent prospect in both terms of habitability and resources, coupled with the good chance that any aliens in range of contact would be searching for these types of planets primed for life as we understand it, it seems inevitable that these beings would find us, regardless of whether we broadcast our presence here or not.

However, is this really such a terrible prospect? Consider not the Hollywood predictions of all-out invasion by a superior, relentlessly savage and unforgiving race, but instead the wealth of knowledge that could be shared between us. These beings, even if not developed enough to physically visit our planet, would be in possession of information and technologies unconceived by humans. This provides a myriad of opportunities for progression. Firstly, there is the opportunity for the advancement of biological knowledge and the implications for the discovery of independent genesis on our understanding of life's origins. Are the basic biochemical mechanisms and conditions for life universal? How has evolution by natural selection operated when applied to different circumstances on entirely different planets? Are ecological niches and interactions universal or unique to water-based life? Or how distinct is alien psychology and society from ours? Secondly, if an alien race were capable of interstellar travel with relative ease, could this forge the potential for trade and economic expansion for both parties?

Although some may argue that this pursuit of knowledge for knowledge's sake is not worthwhile, this opinion seems closed-minded to me. This wealth of information would be applied to problems here on Earth, and may provide easy solutions to many societal and technological issues, without which we would have to spend decades solving. This could also extend to more

Sarah Bunney and Seb Daniels discuss whether we should try to communicate with extra-terrestrial life. While Sarah Bunney argues why we have nothing to fear in doing so, Seb Daniels argues why we shouldn't extend our friendship to outerspace.

dramatic problems such as aid or rescue from planetary disaster, be it via advice on sustainable ecosystem use, or even direct rescue from some apocalyptic event. Additionally, we may not be the first alien race to be contacted, and that wider co-operation networks may already be in place, thereby exponentially multiplying the potential benefits from contact.

> "WHILST THE 'HOSTILE ALIEN' THEORY IS UNDENIABLY VALID, I MYSELF CANNOT JUSTIFY IT"

Whilst the 'hostile alien' theory is undeniably valid, I myself cannot justify it. Such a visiting alien species in achieving interstellar travel would have to had overcome the problems of surviving sustainably without a host planet or power source, as well as engineering craft large and advanced enough to support a large colony over many generations. Therefore destroying life on Earth, or even just human life, would be like shooting fish in barrel – a pointless exercise for organisms tens of thousands of years more advanced than ourselves. Aliens surely could have not achieved such advancement without also developing an intensely co-operative and peaceful society, so the aforementioned benefits of contact for them would outweigh the pointless slaughter of humans for our planet's already diminishing resources. ■

Sarah Bunney is studying for an MRes in Computational Methods in Ecology and Evolution

I will start with a crucial clarification. I do not believe there is a question of if we will make contact, but a question of when we will make contact.

This does not mean it will necessarily happen any time soon, but statistically speaking we are certainly not alone in the universe. With roughly 300 billion stars in the Milky Way, I would happily wager that we are probably not even alone in our own galaxy. But this poses the problem of whether we make the first move. After all, what's the big rush? This isn't an opportunity with an expiry date, and jumping into bed with the first extraterrestrial we can find could have disastrous consequences. So let's take some time as a species to really figure out what we want out of such a relationship and ask ourselves whether we're ready for such a commitment.

Before making contact, perhaps we should take a long hard look at ourselves, and assess whether we really want to be throwing ourselves onto the open market any sooner than absolutely necessary. With discussions from SETI to beam the Internet across the cosmos, will our prospective galactic hook-up be able to see any redeeming qualities through humanity's personal profile, brimming as it is with wars and atrocities? Surely our past tendencies to cause suffering and our obvious taste for destruction and exploitation are far more likely to paint even the most developed nations as savage and barbaric. As a global civilisation, we are still very much stuck in our adolescent years of rebellion and angst with many generations of intellectual growth still to make.

First impressions aside though, it might not be so safe to assume that our potential extraterrestrial neighbours would have purely altruistic intentions. A more developed alien race might not be so different from us, having already exhausted their own local resources we could be easy pickings, naively waving in our cosmic conquistadores with open arms. Our primitive planetary defence system no better than bows and arrows to their muskets and cannons. Stephen Hawking has warned of the dangers that such space-faring nomads may pose to us, and drawing attention to ourselves may constitute an unnecessary threat to humanity. Sure such beings might come in peace, but we have no way of discerning the level of risk involved. So is it really worth the gamble?

But what if the roles were reversed? One day we too will be intrepidly exploring our Galaxy as our civilisation expands beyond our Sun in an inevitable evolutionary step for the human race. As we travel between the stars should we be meddling with civilisations less developed than our own, or avoid interference completely? It would become necessary for us to consider the ethics of such contact, perhaps adopting the so-called Prime Directive from the Star Trek franchise.

"History has proven again and again that whenever mankind interferes with a less developed civilization, no matter how well intentioned that interference may be, the results are invariably disastrous" (Jean-Luc Picard, 2364).

This would not be for our own sake, but for theirs. Like some un-contacted tribes deep in the Amazon, our influence may obstruct their right to self-determination. Not to mention the potential risk of contamination that may arise from our differing immunities. It would be no less than embarrassing if we were to introduce an entire civilisation to the common cold before they can even invent the handkerchief.

When it comes to making alien contact, playing hard to get might just pay off in our favour. For the time being – let's play it cool, and wait for them to call! ■

Seb Daniels is studying for an MSci in Science Communication

TALKING TREES?

Sam Harris-Weatherbee reveals how plants speak to each other.

Slowly scientists are discovering the alien 'languages' and complex networks used by plants to exchange information, and even new evidence that suggests plants can communicate with sound like us.

Are plants even communicating? Some scientists argue that communication implies a purposeful and conscious exchange of information, but plants simply have automatic responses to cues like changes in their environmental conditions or herbivore attack.

Plants can gain a lot from sharing information with each other. For instance, Acacia trees release a chemical warning, ethylene, into the air when they're being grazed upon. Within ten minutes the neighbouring trees will produce toxic levels of tannin in their leaves to deter the herbivores from eating them. Like animals alerting each other to predators, this gives them a better chance for survival.

Plants and fungi have a symbiotic relationship called mycorrhizae, which offers a different warning delivery system. Mycorrhizal fungi colonise the roots of plants and trade nutrients like nitrogen for the carbon generated in plant photosynthesis. The fungi also link between multiple plants, forming a complex network through which the plants can share information. Broad beans use the mycorrhizal network to warn their neighbours when aphids attack them. These neighbours will then increase their chemical defences to deter the aphids and attract their natural predator, wasps.

Plant communication doesn't always work to the benefit of all those involved. There are equally interesting examples of subterfuge. For example, the parasitic Dodder vine uses a long probe inserted into its host to drain the victim of fluid. Jim Westwood at Virginia Tech has shown that the Dodder is doing more than feeding off its host, it's also exchanging messenger RNA. He suspects this allows the Dodder to disable its victim's natural defences, allowing the parasite to continue feeding unhindered.

Mechanisms for plant communication don't always have to be so unfamiliar to our own. Recently scientists have started asking whether plants use sound like us.

> "SCIENTISTS HAVE STARTED ASKING WHETHER PLANTS USE SOUND LIKE US"

Soundwaves are vibrations that occur at different frequencies. Soil and water carry vibrations much more effectively than air, making them ideal channels for transmitting small vibrational signals across the short distance between plants.

Plants can receive sounds: roots will grow toward particular vibrational frequencies like the sound of running water. Producing sound is a very different matter and, in the past, all sounds emitted by plants were dismissed as by-products of the water transport systems, just as gurgles heard from the human gut are a by-product of digestion. But when Monica Gagliano at the University of Western Australia listened to the roots of corn seedlings she discovered that they frequently 'clicked' audibly.

The question remains; can plants use sound to communicate? Chilli plants grow stronger and faster next to 'friendly' neighbouring plants like basil that helps inhibit weed growth and deter pests. In another study, Monica discovered that when all known forms of plant communication and signalling were blocked, chilli plants still grew stronger next to basil. Somehow they knew who was growing next door and Monica speculates that acoustic vibrations are involved. This could be an intentional exchange between plants or the chilli may be receiving and reacting to unintentionally generated vibrations. Unfortunately, scientists are still unsure of how plants produce or receive sound.

What is clear is that our ability to understand these processes might be largely limited by our capacity to perceive them. ■

Sam Harris-Weatherbee is studying for an MSc in Science Communication

IMAGE: Flickr/Bradjward

BOOK REVIEWS

by Neil Stoker

EXPANDING UNIVERSE

TASCHEN

The impact of the Hubble space telescope, launched almost exactly 25 years ago by space shuttle, has been quite extraordinary. Astronomy, our oldest science, has been reborn, and we can all share in it in a way that has never been possible before. The Hubble, in its short life, has been able to multiply the known universe to mind-boggling numbers. And even more dramatically, we all get to see the pictures for ourselves.

So I strongly recommend this beautiful book published by Taschen, who are perhaps fittingly better known for aesthetics than for science. Hubble pictures are all around us, in the newspapers, or in 'pictures of the day' from NASA, but I think it's a joy to sit and just look at these large, high quality images that no-one in the history of the world has had the privilege to see before.

The book is organized in sections that start closer to home in the solar system. We have photographs of planets, moons and comets, before we move out to the Milky Way, mere thousands of light years away, and continue until we are billions of light years from home. Although most of the book consists of Hubble images, there is some text, but (rightly) not too much, and what there is is in English, French and German.

At £30 from Amazon, this book costs more than you might normally spend on a book, but for the universe, it's a snip! ■

Neil Stoker is studying for an MSc in Science Communication

by Holly Bestley

THE GENERATION

BY HOLLY CAVE

The Generation is Holly Cave's first novel, set in a dystopian London of the mid twenty-first century - a future governed by a totalitarian state which forces compulsory genetic screening at birth. The book explores ideas of identity in a world where you are told exactly who you are going to grow up to be.

The action revolves around a small group of individuals in their early twenties, grappling with ideas of identity that, in places, hit fairly closely to home. Cave's writing can feel very honest and in places cut straight to the heart of an emotion. She couples this with moments of stunningly beautiful description, encapsulating a setting with an amazingly simple clarity.

The novel takes on some fairly current scientific topics, from prenatal genetic screening to genetic control of sexual orientation, and manages to give the dystopian future setting a fairly new angle. Despite this, such a state controlled version of the future feels overdone in fiction and even though Cave gives it an interesting angle, this doesn't ever feel fully realised within the book. There is a continual introduction of new ideas throughout, each deserving of its own investigation but none receiving more than a cursory pondering pause.

Saying this, I did find myself drawn into the world painted by the novel. I didn't feel that the novel lived up to how promising it seemed from the first few chapters, but the moments of beauty drew me back in and in places it showed a fantastic use of pace. ■

Holly Bestley is studying for an MSc in Science Communication

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